

FLOW MODELING OF SUPERCRITICAL CO₂ INJECTION AT THE FRIO BRINE PILOT

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RESEARCH OBJECTIVES

Geologic sequestration of CO₂ in brine-bearing formations has been proposed as a means of reducing the atmospheric load of greenhouse gases. Numerous brine-bearing formations have been identified as having potential for geologic sequestration of CO₂. One promising setting is the fluvial/deltaic Frio formation in the upper Texas Gulf Coast, which was the site of a CO₂ sequestration pilot in October 2004. The objective of this research was to investigate the physical processes controlling the behavior of CO₂ in the subsurface during the pilot, by means of numerical modeling. Sensitivity simulations were conducted to help design the pilot, predictive simulations were used to assess our state of understanding of the issues accompanying CO₂ sequestration in brine-bearing formations, and calibration simulation results were compared to results of the pilot to improve that understanding.

APPROACH

The numerical simulator TOUGH2, developed at Berkeley Lab, is used to model the flow and transport processes occurring during the Frio Brine Pilot. TOUGH2 considers all flow and transport processes relevant for a two-phase (liquid-gas), three-component (CO₂, water, dissolved NaCl) system. In the subsurface, supercritical CO₂ forms an immiscible gas-like phase and partially dissolves in the brine. Under the pilot conditions ($P = 150$ bars, $T = 55^\circ\text{C}$, $\sim 100,000$ ppm salinity), supercritical CO₂ is strongly buoyant compared to the native brine.

A three-dimensional numerical model of the pilot site was developed over the months preceding CO₂ injection, beginning with a simple model, and adding more detail and realism as results of site characterization studies became available. The final model consists of 23 m thick brine-saturated sand near the top of the Frio within a 900 m x 900 m partially sealed, dipping fault block. Two wells penetrate the sand, one injection well and one observation well, both of which are perforated over the upper quarter of the sand thickness.

ACCOMPLISHMENTS

Sensitivity modeling helped decide practical questions such as which of several upper Frio sands to inject into, how far apart the injection and observation wells should be (in particular showing that existing wells were too far apart, necessitating the drilling of a new injection well), how much CO₂ to inject and at what rate.

Modeling of hydrologic tests helped in the design of pre-injection, site characterization pump and tracer tests to optimize the information gained on formation flow properties, *in situ* phase conditions, and fault-block boundary conditions. Predictive modeling of CO₂ movement between wells (Figure 1 and Table 1) has illustrated the complex interplay between phase interference and buoyancy flow that occurs as CO₂ is injected into a high-permeability, steeply dipping sand layer, and the ability of the model to reproduce it. By running simulations with a range of parameters and comparing model results to field data, we have greatly improved our understanding of these flow processes. Generally good agreement between observed and modeled CO₂ and tracer travel times between injection and observation wells has validated our ability to model CO₂ injection, while minor discrepancies have pointed out areas where future research is needed.

Table 1. Comparison of observed and modeled CO₂ arrivals at the observation well

	Event	Time (days)
Field	Immiscible CO ₂ arrival at observation well	2.1
Model	Dissolved CO ₂ arrival at observation well	2.8
	Immiscible CO ₂ arrival at observation well	3.0

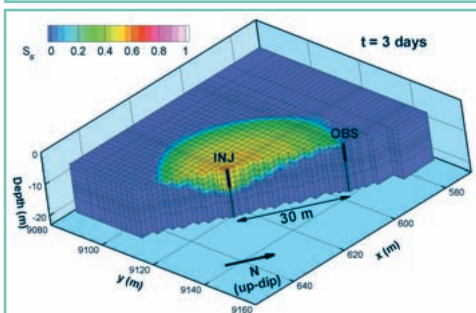


Figure 1. Modeled distribution of CO₂ in the immiscible gas-like phase after 3 days of injection at the Frio Brine Pilot, where CO₂ was injected at an average rate of 180 metric tons per day for nine days. The injection and observation wells are displayed as black lines, with the perforated intervals shown thicker.

SIGNIFICANCE OF FINDINGS

This work has demonstrated that we have a good understanding of the complex multiphase flow processes involved in CO₂ injection, as well as an effective modeling capability for designing future CO₂ injection tests and investigating CO₂ sequestration scenarios.

RELATED PUBLICATION

Doughty, C., and K. Pruess, Modeling supercritical CO₂ injection in heterogeneous porous media. *Vadose Zone Journal*, 3(3), 837-847, 2004. Berkeley Lab Report LBNL-52527.

RELATED WEBSITE

<http://www-esd.lbl.gov/GEOSEQ/index.html>

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